Faculty of Computer Science and Information Technology

Centralized Intelligent Network Management for Energy Efficient Resource Mechanism in Small Cell Network

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Centralized Intelligent Network Management for Energy Efficient Resource Mechanism in Small Cell Network

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DECLARATION

I declare that the work in this thesis was carried out in accordance with the regulations of Universiti Malaysia, Sarawak. Except where due acknowledgements have been made, the work is that of the author alone. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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Signature

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DEDICATION

This thesis is dedicated to Allah Who

“(3) Created man, (4) [And] taught him eloquence”

(Holy Qur’an verses 3 and 4)

and

“(4) Who taught by the pen – (5) [and also] Taught man that which he knew not”

(Holy Qur’an 96 verses 4 and 5).

and

To the memory of my late parent

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ABSTRACT

Wireless Heterogeneous Small Cells Network (WHSCN) raised an enormous interest among communication industry and academia all around the world. Recent development of mobile services and applications has resulted in an imposing rise in the network traffic. In order to enhance the network capacity to meet the traffic demands, the Service Providers (SPs) make use of dense deployment of small cells base stations. However, dense deployment of small cells poses several challenges such as inefficient utilization of resources, imbalance of load during peak-hours and underutilization of resources during off-hours leading to high energy consumption and hence degrading the network efficiency of WHSCN. In order to address these issues, this research has proposed a centralized Intelligent Network Management (INM) mechanism. The INM mechanism is implemented in a centralized Small Base Station (SBS). This centralized SBS is known as High Signal Strength (HSS-SBS). The proposed INM mechanism has efficiently utilized the resources by monitoring the load of each SBSs in a cluster. INM also shares the SBSs' load by activating the centralized SBS during peak-hours and reducing high energy consumption by deactivating the under loaded SBSs during the off-hours. The simulation results show that the proposed mechanism outperforms in terms of decreased user rejection ratio only 3% during peak-hours while 30% reduced energy consumption as compared to Mobility Load Balancing (MLB) scheme of Random Sleep SBSs (RS-SBSs) and Sleep Only Centralized SBS (SOC-SBS) scheme during off-hours. Thus, the proposed INM mechanism has proved to be a better solution to address the issue of inefficient utilization of resources, imbalance of load sharing and energy inefficiency in the WHSCNs.

Keywords: Wireless small cell heterogeneous network, small base stations, service providers, intelligent network management, energy efficiency.

Mekanisme Pengurusan Sumber Tenaga yang Cekap untuk Rangkaian Sel Kecil

ABSTRAK

Rangkaian Sel Kecil Tanpa Wayar (WHSCN) menimbulkan minat yang besar di kalangan industri komunikasi dan ahli akademik di seluruh dunia. Perkembangan perkhidmatan mudah alih dan aplikasi baru-baru ini telah mengakibatkan kenaikan trafik rangkaian. Bagi meningkatkan keupayaan rangkaian untuk memenuhi permintaan trafik, Penyedia Perkhidmatan (SPs) memanfaatkan penempatan padat di stesen pangkalan sel kecil. Walau bagaimanapun, penggunaan padat sel-sel kecil menimbulkan beberapa cabaran seperti penggunaan sumber yang tidak cekap, ketidakseimbangan beban semasa waktu puncak dan penggunaan sumber yang tidak sepenuhnya (under utilization) semasa bukan waktu puncak sehingga menyebabkan penggunaan tenaga yang tinggi dan mengurangkan kecekapan rangkaian WHSCN. Untuk menangani isu-isu ini, penyelidikan ini telah mencadangkan mekanisme Pengurusan Rangkaian Pintar (INM) berpusat. Mekanisme INM dilaksanakan di Stesen Pangkalan Kecil (SBS) yang terpusat. SBS yang berpusat ini dikenali sebagai Kekuatan Isyarat Tinggi (HSS-SBS). Mekanisme INM yang dicadangkan telah menggunakan sumber dengan cekap dengan mengawasi beban setiap SBS dalam setiap kluster. INM juga berkongsi beban SBS dengan mengaktifkan SBS berpusat pada waktu puncak dan mengurangkan penggunaan tenaga yang tinggi dengan menyahaktifkan SBS semasa bukan waktu puncak. Hasil simulasi menunjukkan bahawa mekanisme yang dicadangkan adalah lebih baik dalam mengurangkan nisbah penolakan pengguna sebanyak 3% semasa waktu puncak dan mengurangkan penggunaan tenaga sebanyak 30% jika dibandingkan dengan Skim Imbuhan Beban Mobiliti (MLB) berdasarkan masa Tidur Rawak SBS dan Skim SBS Tidur Berpusat (SOC-SBS) semasa bukan waktu puncak. Oleh itu, mekanisme INM yang dicadangkan telah menjadi satu penyelesaian yang lebih baik *untuk menangani masalah penggunaan sumber yang tidak cekap, ketidakseimbangan perkongsian beban dan ketidakcekapan tenaga dalam WHSCN.*

Kata kunci: *Rangkaian sel kecil pelbagai tanpa wayar, stesen pangkalan kecil, penyedia perkhidmatan, pengurusan rangkaian pintar, kecekapan tenaga*

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LIST OF ABBREVIATIONS

1G	1st Generation
2G	2nd Generations
3G	3rd Generations
3GPP	3rd Generation Partnership Project
4G	4th Generations
4 G-LTE	4th-Generation-Long-Term Evolutions
5G	5th Generations
ADNSF	Access Network Discovery and Selection Function
AF	Amplify-and-forward
ANDSF	Access Network Discovery and Selection Function
BS	Base Station
CA	Carrier Aggregation
CL	Current Load
CDMA	Code Division Multiple Access Technique
COFDM	Coded Orthogonal Frequency Division Multiplexing
CN	Core Network
CRAN	Cloud RAN
CSI	Channel State Information
D2D	Device-to-Device
DB	Database
DBS	Database System
DF	Decode-and-forward
DL	Downlink

DSL	Digital Subscriber Line
DRAN	Distributed RAN
EARTH	Energy Aware Radio Technologies
EE	Energy Efficiency
ENodeB	Evolved Node B
ERULB	Efficient Resource Utilization and Load Balancing
FDMA	Frequency Division Multiple Access
Gb	Gigabits
GoS	Grade of Service
GR	Green Radio
GSM	Global System for Mobile
GSM	Global System for Mobile
GUIDE	Graphical User Interface Development Environment
HCGAA	Hybrid Channel Gain Access Aware
HDTV	High Definition Television
HetNets	Heterogeneous Networks
HEW	High Efficiency WLANs
HSR	High Signal Range
HSS	High Signal Strength
HPNs	High power nodes
ICI	Inter-cell interference
INM	Intelligent Network Manager
INMC	Intelligent Network Manager Layer Controller
INML	Intelligent Network Manager Layer

InPs	Infrastructure Providers
IMT-Adv	International Mobile Telecommunications-Advanced
IOT	Internet of Things
ITU	International Telecommunications Union
KJ	Kilo Joule
LB	Load Balancing or Balancer
LBRL-T	Reinforcement Learning of Macro Cell-Throughput
LC	Load Controller
LD	Load Dividing or Divider
LPNs	Low power nodes
LSR	Low Signal Range
LTE	Long Term Evolution
MBS	Macro cell Base station
MCF	Multi-Criteria Function
MeNB	Macro Evolved Node B
MIMO	Multiple Input Multiple Outputs
MB	Mega Byte
MLB	Mobility Load Balancing
MM-Wave	Millimeter Wave
Multi-RS	Multi-Relay Station
MVCE	Mobile Virtual Centre of Excellence
MVNOs	Mobile Virtual Network Operators
NTR	Non-Transparent Relay
NVS	Network Virtualization Substrate

OPEX	Operational expenditure
PeNB	Pico Evolved Node B
PL	Previous Load
PNC	Physical Network Controller
PNRL	Physical Network Resource Layer
PNRLC	Physical Network Resource Layer Controller
PR	Physical Resource
PRB	Physical Resource Blocks
RACH	Random Access Channel
RL	Reinforcement Learning
RBS	Relay Base Station
RSRP	Reference Symbols Received Power
RSRQ	Reference symbols received quality
QL	Q-Learning
QoS	Quality of Service
RACH	Random Access Channel
RAN	Radio Access Network
RANaaS	Radio-Access-Network-as-a-Service
RAT	Radio Access Technologies
RBS	Relay cell Base station
RBs	Resource Blocks
RRM	Radio Resource Management
RS	Reference Signal
RS-SBSs	Random Sleep Small Base Stations

RRA	Radio Resource Allocation
RSI	Resource State Information
RSRP+CRE	Reference Signal Receive Power plus Cell Range
SBS	Small cell Base station
SCNs	Small Cell Networks
SCs	Small Cells
SINR	Signal to Interference-plus-Noise Ratio
SNR	Signal to Noise-Ratio
SOC-SBS	Sleep Only Central Small Base Station
SON	Self-Organizing Network
SPs	Service Providers
UDNs	Ultra-Dense Networks
UE	User Equipment
UL	Uplink
VBs	Virtual Base Stations
WANs	Wireless Access Networks
WHN	Wireless Heterogeneous Network
WiFi	Wireless Fidelity
WLAN	Wireless Local Area Network
WSCNs	Wireless Small Cell Networks
WVN	Wireless Virtualized Network

CHAPTER 1

INTRODUCTION

1.1 Background of the Study

In order to meet the demand of wireless networks coverage capacity a design paradigm called the Heterogeneous Network (HetNet) was introduced in Long Term Evaluation (LTE) (Li et al., 2015; Marsan et al., 2013). The idea of HetNet is to deploy several small cells under the coverage of macro cells to extend coverage and to boost capacity in certain high-demand urban areas (Li et al., 2015). HetNet represents a major paradigm shift in cellular network designs and offers enhancement in network and coverage. The HetNet introduced small cell and the network of small cells is called Small Cell Network (SCN). The small cells have short range coverage area, low cost and low power cellular base station designed for small business environment (Tao et al., 2019; Dahlman, et al., 2014). According to Ming-Chin et al. (2015), the purpose of small cells is to enhance communication quality when the user is located in a weak signal area such as the boundary of a base station coverage and basement of a building. Moreover, small cells also share the macro cell load in wireless network.

A small cell is a cellular coverage area, which is served by a low-power Small Base Station (SBS) (Qutqut, 2014). SBS is a fully featured Base Station (BS) that is typically intended to be user-deployed for indoor deployment such as offices, residential homes, shopping malls, railway stations, airports, subways, highways and backhaul to the operator's Core Network (CN) via internet connection such as Digital Subscriber Line (DSL) and cable (Qutqut, 2014; Inform and small cell Forum, 2013). There are different types of small cells like femto, pico, micro and macro. The femto cell is the shortest coverage area. Therefore, it is the smallest type of small cell. The range of femto cell is up to 100 meters. It is used for indoors like offices and homes. The Pico is the second smallest type of small cell which covers maximum of 200 meters. It is also used for indoors like homes and offices. The micro cell coverage area is up to 1000 meters i.e. 1 km. The use of the micro cell is high due to its high coverage capacity as compared to femto and Pico which are mostly deployed at the public places such as shopping malls and railway stations. The biggest type of small cell is called macro cell and its coverage is 3 to 5 km in diameter that can be enhanced and mostly deployed at the universities, airports and highways (Electronic design, 2018; Mobile network guide, 2018; Bernard, 2014).

Normally in the urban areas the number of users increase during daytime working hours. In literature, the increase of users increases the users' load on a network. While the period of users' high load is called peak-hours. In addition, a base station reaching 90% of its load capacity is known as loaded state. So, when the users' load is high during peak-hours the small cell base stations of urban area reach the loaded state. Consequently, the users of urban area will be facing the problem in accessing the network for availing the services. In this scenario where the number of users increases rapidly during peak-hours, the dense deployment of SBSs is a prerequisite by operators to extend the network coverage and to facilitate the maximum users (Musleh et al., 2017; Wang et al., 2016). Therefore, operators deploy more SBSs to serve more users and enhance the network coverage. Normally the operators increase the number of SBSs to handle the peak-hours load.

However, these dense deployments of SBSs are not efficiently utilized during normal and off-hours. Thus, some SBSs are serving many users whereas some are serving only a few ones in the SCN of urban areas. In literature, this issue is called inefficient utilization of resource and imbalance of load among SBS. Therefore, the extension of